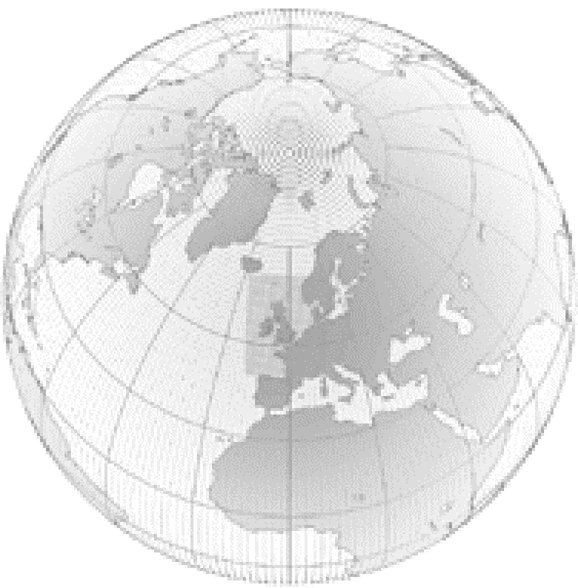
Numerical Weather Prediction

Impact of Additional UK Radiosonde Ascents on NWP Forecasts of Trough Disruption Events



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by
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1. Introduction.

Slow moving cut-off circulations that form when an upper-level trough disrupts are often associated with large precipitation accumulations (see pages 163-6 of the Forecasters' Reference Book, 1993). For this reason, correct representation of trough disruption events in NWP forecasts is very important to achieve good quality guidance for public forecasts.

The 'Review Of Public Forecasts and Warnings' (UK Met. Office, 1993) identified the poor handling of trough disruption events by the Limited Area Model (LAM) over the United Kingdom as a major cause of errors in summer-time rainfall forecasts, and noted that predictions of trough disruption 'may depend more critically on the detail of the analysis than most synoptic predictions'. One of the recommendations was to 'consider what improvements to the observing network would be helpful in these cases'. This paper will present the findings from an experiment involving the launch of extra radiosondes during the summer of 1994.

2. The Extra Observations and Choice of Cases.

The purpose of the experiment was to assess the benefit of extra radiosonde ascents from a selection of UK stations (shown in Fig.1). This was judged to be an easy option, as, with the help of OP-Division and all the stations involved, the launch of extra sondes could be implemented at short notice (just 6 hours was required at most stations). It was realised that extra data from the UK radiosondes would be unlikely to have a marked impact on the flow dynamics when troughs disrupted over the Atlantic. However, by improving the analyses (particularly of the moisture field) in the low-level warm moist air ahead of the trough as it approached the UK, there was scope for improving the rainfall forecasts.

To identify forthcoming trough disruption events which might be suitable subjects for a campaign, the operational forecasts were monitored daily during August 1994, and guidance was provided by the medium range forecasters in CFO. It was hoped to study at least one example in which either disruption occurred over the UK or an already formed cut-off moved across the UK. However, because of limited time (the study was concerned with summer-time rainfall), less ideal examples were also considered.

The criterion for initiating an Intensive Observing Period (IOP) was that the upper trough should be close enough to the UK for the sonde data to have potential for impact. In certain cases, part of the UK network was deemed to be too far from the important features of the trough to make any impact and, as an economy measure, extra ascents were not requested from these stations.

Eight UK upper-air stations participated in the experiment. At these stations, radiosondes were released every three hours, rather than at the normal six-hour frequency.

There now follows an overview of the synoptic situations that were investigated. There were three IOPs in August 1994.

- IOP 1 was conducted between 12Z on August 2nd and 12Z on August 4th. During this period a trough had already disrupted, with an upper-level low west of the UK (see Fig.2, showing the 500 hPa height field at 06Z on the 3rd). Extra sondes were released from six stations; Boulmer, Hillsborough, Aughton, Hemsby, Camborne and Herstmonceux.

- IOP 2 took place between 00Z on August 23rd, and 00Z on August 26th. During the latter part of this period, the upper winds over the UK were northwesterly, and consequently observations over the UK were thought likely to influence the forecast of trough extension further downstream over Western Europe (see Fig.3). Extra sondes were launched from all eight stations (including Lerwick and Stornoway), until later during the 25th, when the Scottish stations were excluded, being considered unlikely to give any impact.

- IOP 3, the final campaign, was conducted between 00Z on August 31st and 00Z on September 2nd. Of the three IOPs, this period was the most interesting because a trough was in the process of disrupting over the UK, and a cut-off formed over East Anglia (see Section 4.2). Extra sondes were released from all the stations except Lerwick and Stornoway.

3. The Model Experiments.

To assess the impact of the extra observations, a number of LAM re-runs were performed. These runs involved three modes of radiosonde input; the 'NO OBS' runs with no UK sonde data used during the assimilation step, the 'OP OBS' runs using the normal operational sonde network, and the 'ALL OBS' runs using all the sondes including all the extra ascents at 3-hourly intervals.

Firstly, 14 cases covering all the IOPs were looked at, to assess the impact of the UK radiosonde network as a whole on the forecasts of for example PMSL, rainfall, θw and 500 hPa height. Runs were performed both with and then without the enhanced sonde network.

After initial results were analysed, the five cases with the most notable ALL OBS/NO OBS differences were chosen for further assessment, involving more detailed comparison of results and some attempt at verification. These later runs were concerned with assessing the impact of the extra sondes over and above the operational sonde network (ie. comparing the ALL OBS forecasts with those from the OP OBS runs).

The re-runs of the LAM were performed to mimic as much as possible the operational suite, i.e. a 12-hour assimilation to 00Z or 12Z, followed by a 36-hour forecast. As an example, the extra sonde data from the additional ascents at 15Z and 21Z on August 2nd were used in the assimilation step preceding the 00Z ALL OBS forecast on August 3rd. Thus, during IOPs involving all eight UK stations, there was a total of 16 extra ascents included in the 12 hours of assimilation preceding the ALL OBS model runs.

4. Results.

4.1. Results From All Cases.

The main result, discussed in greater detail below, was that the impact of the extra radiosonde ascents to the forecast of most of the fields was very small.

In general, at T+00 and T+06 there were some noticeable differences between the ALL OBS and NO OBS re-runs in some of the forecasts of rainfall rates and accumulations, and small differences in the θw (no greater than 1.0 K), relative humidity and vertical velocity at different levels. There were also small differences in the values of PMSL (no greater than 0.5 hPa).

In all the runs after T+06, the ALL OBS and NO OBS fields converged as their forecasts proceeded, showing that the larger scale processes eventually dominated the evolution. Adding UK radiosonde information only influenced the forecasts on a relatively short timescale.

Of all the fields, the rainfall accumulations gave the largest differences between the runs. Table 1 summarizes the largest differences. Down the left hand side are the five selected cases, whilst along the top are the validation times. All the figures in the boxes represent 6-hourly accumulations of rainfall (in mm) up to the validation time shown. The figures on the right hand side of each box are the largest differences between the ALL OBS and the OP OBS runs. (Most of these were over the British Isles, rather than further downwind, as would be expected in a slow moving synoptic situation). The figures on the left hand side are the corresponding accumulations from the ALL OBS runs. By viewing both sets of figures it is possible to assess the percentage impact of the extra sondes. Note that in most of the cases, the ALL OBS run produced more rainfall than the OP OBS run (i.e. most of the largest differences are positive). The two figures underlined show the biggest differences, and both occur early on in the runs. After this, as with the other fields studied, the differences diminished as the forecasts converged.

4.2. More Detailed Results From Case 5.

The example which follows is for Case 5 in Table 1, from the forecast of 12Z, 31/8/94. It was chosen because it showed the largest difference in the rainfall accumulations between the runs with and without the extra sonde data, and because it is a typical example of the kind of weather system which can cause problems for forecasters.

Fig.4 shows the 12Z, 31/8/94 forecast for the 500 hPa field from the run using the operational radiosonde network (with the 6-hour launch frequency). A trough is situated over the UK which is forecast to deepen slightly and, by T+18, cut-off over East Anglia. This was in fact a good forecast.

The surface charts in Fig.5 forecast the surface low to deepen and move northeastwards across the SE of England. The associated rain area is forecast to wrap around the low, producing continuous rainfall over the SE of England between T+6 and T+24.

4.2.1. T+12 Results.

The T+12 forecast was compared with the actual surface analysis, shown in Fig.6, and the radar image for that verifying time. The forecast for the PMSL is good. However the rainfall area has not been so well predicted. The region of continuous moderate rainfall over the Midlands and NE of England has not been forecast at all, and also the western boundary of the rain area does not extend far enough across the Irish Sea in the model output.

There is obviously room for improvement in the rainfall forecast, but did the extra sondes have a positive impact? Fig.7b shows the T+12 forecast from the ALL OBS run, and confirms that there was no significant impact on the rainfall rates, when compared to the OP OBS run, shown again in Fig.7a.

The lack of impact was also seen in the rainfall accumulations. Fig.8 shows three frames of the accumulations over England and Wales for the case of 12Z on 31/8/94. The top two frames show the forecast accumulations for the 6 hours leading up to T+12 from the runs with and without the extra sonde ascents. There is very little difference in the results. The bottom frame shows values of the actual 6-hourly accumulations, retrieved from the Station Forecast Database (Radford, 1991) comprised of records at 57 stations around the UK. Both forecasts can be seen to have missed the detail in the rainfall pattern over the SE of England, and also the areas of high rainfall over Anglesey and the NE of England. In short, both forecasts are closer to each other than they are to reality.

The extra radiosonde observations acquired during the IOPs were also used in the Mesoscale Model (MES) assimilations. The MES rainfall forecasts were checked with a view to assessing whether it was worth repeating any of these runs. The instantaneous rainfall rates at T+12 on the mesoscale forecast of 12Z, 31/8/94 (Fig.9) show a slight improvement over the LAM forecast (Fig.7b) when compared to the observations (Fig.6). There has been a better estimate of the rainfall over the NE and E of England, and also the shape of the moderate rainfall area over the Midlands is better represented. However, the model still fails to pick up the moderate rainfall over Anglesey, and the western boundary is still not predicted to extend over the Irish Sea.

The MES 6-hour rainfall accumulations leading up to T+12 (Fig.10) show little improvement over the LAM values (Fig.8). The basic shape of the rain area covering the SE of England is similar to that in the LAM, and still does not pick up any of the details seen in the observed rainfall amounts. Note also the large accumulations missing over the NE of England and over Anglesey.

The similarity between the different resolution model forecasts suggests that the impact of the extra data on the MES forecasts was also small and that there is little to be gained from more detailed studies using the Mesoscale model in these cases.

4.2.2. T+00 Results.

As shown in Table 1, there was a large difference in the rainfall accumulations seen at the analysis time in this example. Although any impacts at T+00 would be of little use to the forecaster, because of the time delay in receipt of the analysis in CFO, it was thought that limited verification of these differences would be useful in order to assess the impact of the extra observations on the assimilation.

Fig.11 shows the ALL OBS, OP. OBS and actual rainfall accumulations over the SW of England and Wales for the 6 hours leading up to T+00 in the 12Z, 31/8/94 case. The difference of 5mm highlighted in Table 1 can be seen over Exeter. Both forecasts have missed the peak accumulation implied by the 15mm value over Yeovilton, though the forecast without the extra sondes has made a better estimate of the total. Over the far SW though, the run with the extra sondes has made the better forecast of the 'Trace' values observed.

5. Conclusions and Further Work.

- The effect of extra radiosonde data over the UK during the episodes of trough disruption brought little, if any, improvement to the forecasts beyond T+06 of most fields, including PMSL, θw, RH, and rainfall.

- Moderate impacts were seen in the rainfall fields at the analysis time, T+00, and early in the forecasts. Accumulations differed by as much as 5.5mm. However, the impacts became insignificant by T+12.

- The differences between the model and observed rainfall fields were not diminished by the extra radiosonde ascents.

These findings may at first seem a little disappointing, but they are still worth reporting. As with all data impact studies of this kind, there is no guarantee that the model forecasts during a campaign will be sensitive to extra data. It seems that in the cases studied, the forecasts of PMSL from the runs with the normal sonde network were generally good, and there was therefore little room for improvement.

Case 5, which was highlighted in Section 4.2, featured an incorrect rainfall forecast. This may have been due to a lack of observations upstream of the UK. Extra observations from data sparse regions to the west and south of the UK might have had more of an impact over the operational forecast. (Grant, Bader and Waters (1995) have suggested that data sparsity in the Bay of Biscay may be an important and regular source of forecast error (not just for trough disruption). The situation may be exacerbated further by future economies in the sonde network (for example, the Portuguese Met. Office no longer commission any ascents at Lisbon due to financial constraints - Maria Monteiro, personal communication)).

A useful follow-up experiment would be to assess the benefit of dropsonde data over the North Atlantic, the sondes being released from the Met. Research Flight C–130 aircraft along selected flight paths into areas thought to be crucial to the disruption development. This campaign would be more difficult to implement (with operational difficulties including the requirement of 48 hours notice and the limited availability of the aircraft), as well as being much more costly. However, the advantages of acquiring new data in a normally data-sparse area, and the greater potential for sampling incipient trough disruption upstream of the UK (with the C–130 flying out to between 20 and 30°W), mean there would be a higher chance of a good positive impact.

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References.

United Kingdom Met. Office, 1993: 'Forecasters' Reference Book'.

United Kingdom Met. Office, 1993: 'Review Of Public Forecasts and Warnings'.

Radford, A.M., 1991: 'Station Forecast Database (SFD) Specification', Verification System Documentation Paper No. B/D3/1.

Grant, J.R., Bader, M.J. and Waters, A.J., 1995: 'Forecasting Thunderstorms in "Spanish Plumes"', NWP-Division Technical Report No.170.

Table 1: The effect of adding the extra radiosonde ascents on the forecast values of 6-hr rainfall accumulations. See Section 4.1 for full explanation.

Fig. 1: The eight UK radiosonde stations releasing extra sondes during August 1994.

Figs. 2 & 3: Synoptic charts for IOP 1 (Fig. 2) and IOP 2 (Fig. 3). Charts both show 500 hPa height (contours at 6 dm intervals), and 500-1000 hPa thickness (dashed lines at 6 dm intervals).

Fig. 4: The 12Z 31/8/94 'OP OBS' LAM forecast of the 500 hPa height (contours at 6 dm intervals) and 500-1000 hPa thickness (dashed lines at 6 dm intervals).

Fig. 5: The 12Z 31/8/94 'OP OBS' LAM forecast of the PMSL (hPa) and surface precipitation rate (mm hr^{-1}).

Fig. 6: The surface analysis at 00Z on 1/9/94. The hashed area shows regions of rainfall, whilst the heavily shaded area shows regions of continuous moderate rainfall. (The UK composite radar image at 00Z 1/9/94 was used to aid the rainfall analysis).

Fig. 7: The 12Z 31/8/94 LAM forecasts of the PMSL (hPa) and surface precipitation rate (mm hr^{-1}) from (a) the 'OP OBS' run, and (b) the 'ALL OBS' run, both verifying at 00Z 1/9/94 (T+12).

Fig. 8: The 12Z 31/8/94 LAM forecast of the 6-hr rainfall accumulations (mm) from the 'ALL OBS' run (top left) and the 'OP OBS' run (top right), and the actual 6-hr rainfall accumulations (mm) from the Station Forecast Database (bottom left), all verifying at 00Z 1/9/94 (T+12).

Fig. 9: The 12Z 31/8/94 'ALL OBS' MES forecast of the instantaneous rainfall rate (mm hr^{-1}) at 00Z 1/9/94 (T+12).

Fig. 10: The 12Z 31/8/94 'ALL OBS' MES forecast of the 6-hr rainfall accumulations (mm) between 18Z 31/8/94 (T+06) and 00Z 1/9/94 (T+12).

Fig. 11: The 12Z 31/8/94 LAM forecast of the 6-hr rainfall accumulations (mm) from the 'ALL OBS' run (top left) and the 'OP OBS' run (top right), and the actual 6-hr rainfall accumulations (mm) from the Station Forecast Database (bottom left), all verifying at 12Z 31/8/94 (T+00).